OAR:
The Basic Research Agency
of The United States Air Force

AF OFFICE OF SCIENTIFIC RESEARCH / AF CAMBRIDGE RESEARCH LABORATORIES / AERONAUTICAL RESEARCH LABORATORIES / EUROPEAN OFFICE OAR

NO. 17 5 NOVEMBER 1962

HEURISTIC PROCEDURES IN PROBLEM SOLVING

DR. Charles E. Hutchinson, Behavorial Sciences Division (AFOSR)

Dr. Paul Fitts of the University of Michigan, is directing studies of small group and team factors in the operation of man-machine systems. The discussion that follows describes one task in the program, performed by Theron Stimmel, which dealt with the way people process information in solving problems.

Problem solving by people may involve either the use of an algorithmic or heuristic method or both. An algorithmic procedure involves the use of a prescribed sequence of steps which, if correctly applied, will assure the person of an optimal or perfect solution. A common example of a problem amenable to the use of an algorithmic procedure is the extracting of the square root of a number. The two conditions for the application of an algorithm are: (1) that an algorithm is known, and (2) that it is feasible to apply it in a given situation. If one of these two conditions is not met, then resort is often made to heuristic procedures. As here defined "heuristic" means using the information obtained in one step of a solution to aid in deciding upon the next step; it also means using a problem solving procedure that does not necessarily guarantee an optimal solution.

In the past, experimenters studying human information processing in complex tasks have been primarily concerned with algorithmic procedures. However, a great many of the problems people must solve in everyday life, and many military problems, require the use of heuristic procedures for one of the following three reasons: (1) the person has no algorithma for solving the problem; (2) there is only partial information present; or (3) the cost in time or money makes the use of an algorithm unfeasible. Examples of problems where heuristics are often applied for one or more of these reasons are the scheduling of work by people and/or production machines, the stock market problem, the transportation problem, and the weapons assignment problem.

The transportation problem has been selected for intensive study, chiefly because an algorithm for its solution is known, and hence optimals can be computed but the subject be-

cause of limited time must use heuristic methods. In this problem, the person is asked to make transportation assignments from origins to destinations in such a manner as to minimize the total distance covered by all of the assignments.

Previous studies in this series have approached the understanding of the way people deal with the transportation problem from two directions. The first line of approach has studied the physical features in the problem that influence the quality of performance. For example, work has been done on the difference in performance when the information displayed as a matrix (mileage chart). It has been found that people are able to do significantly better using the map display. Another aspect studied has been the effect of the physical dimensions of the problem on the time and accuracy of solutions.

At the present time an experiment is under way to investigate further the effects of varying the smaller dimensions of the problems upon the time to solve and the quality of solution. In a previous study, it was found that in the matrix problem, performance declined as a linear function of the amount of uncertainty reduced by each decision. At present an experiment is under way to determine if this effect holds for both the map display and the matrix display. Subjects in this experiment will receive far more extensive training than subjects in previous experiments. It is hoped to determine whether previously discovered effects disapper with extensive training, and to study the effects of extensive training on individual differences.

Other current research on the use of heuristics in problem solving is concerned with the effects of past experience and learning variables. Transfer of training effects between displays, the effect of mathematical training, and the effect of extensive training on the strategies people adopt in solving this problem are being studied. The sequences and patterning of decisions are being subjected to an extensive analysis in this work.

General Ostrander Assumes Command

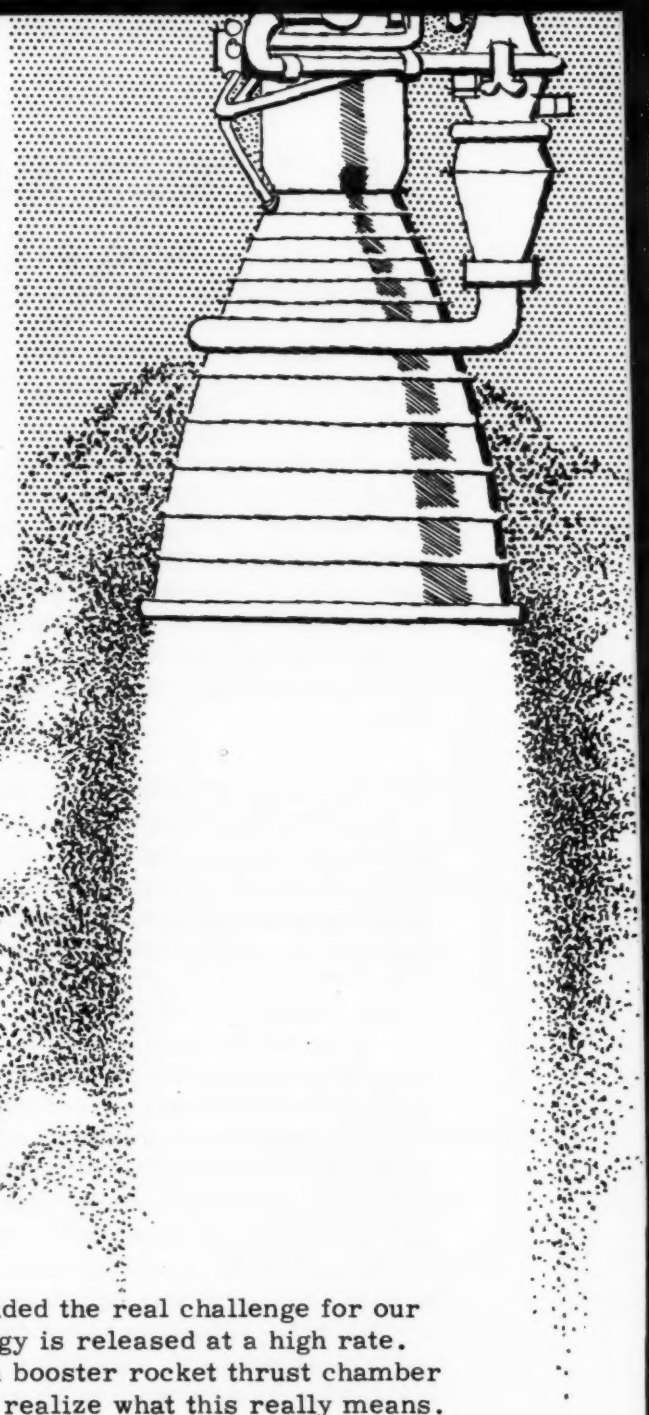
Major General Don R. Ostrander assumed duties as Commander of the Office of Aerospace Research on October 15th.

General Ostrander was Deputy Commander of the Ballistic Systems Division of Air Force Systems Command in Los Angeles, California, prior to his assignment here.

Since 1947, he has been directly connected with aerospace research and development. He also served with NATO in 1958 and 1959 and with the National Aeronautics and Space Administration in 1959-60.

HARNESSING EXPLOSIONS

Bernard T. Wolfson
Directorate of Engineering Sciences (AFOSR)



If one would ask what is the most prominent aspect of modern technological progress, perhaps the best answer would be that it is our ability to handle systems with increasingly high rates of energy release. The atom bomb has proven that in our time the achievement of high rate of energy release presents no problem. But handling, of course, involves quite a bit more than just achieving. The detonation process fed by chemical reactions has been known for some eighty years, but most of the effort in scientific investigations dealing with this phenomenon were directed towards devising means for its prevention rather than for controlled exploitations that are tantamount to handling.

The advent of the space age provided the real challenge for our ability to control systems where energy is released at a high rate. It is enough to witness the testing of a booster rocket thrust chamber or the launching of a space vehicle to realize what this really means. Today to keep such a system under control still implies only preventing it from getting out of hand and safeguarding against uncontrolled detonations. But in our age we have already reached the exciting stage where we can also contemplate the possibility of actually har-

nessing the explosion process itself, so that it could be used directly as the source of power in a rocket thrust chamber.

To achieve our mastery over the detonation, whether our interest is in avoiding or in exploiting it, quite an intimate familiarity with this phenomenon is required. It is with this purpose in mind that Professor A. K. Oppenheim is directing the detonation research at the University of California under the sponsorship of the AFOSR.

The main purpose of this program is to study the physical parameters that govern the acceleration of combustion waves in explosive gas mixtures, and, in particular, the gasdynamic processes that are associated with transition from slow burning to detonation. In the initial phase of this study we have learned how a pressure wave is generated by an accelerating flame and how the fluid motion induced by such a wave promotes the transition from a laminar to turbulent flame enhancing thus quite considerably the development of the process.

At present the onset of the detonation wave itself is under scrutiny. It turns out that this is associated with a kind of point explosion in the turbulent combustion zone. The "explosion in an explosion" produces high-pressure-amplitude oscillations that are similar to the pressure waves that characterize the destructive, high frequency combustion instability in rocket thrust chambers.

In order to develop some sense of value, let us consider the following figures. The flame accelerates normally in a stoichiometric hydrogen-oxygen mixture at a rate in the order of 100,000 g's. If such a mixture is initially maintained at normal temperature and pressure, a detonation velocity of about 2800 m/sec is attained at a distance of 47 $\sqrt{d}$ cm (d being the tube diameter in cm) from the closed end of the tube where the ignition took place. At the onset of the detonation wave the flame travels at a velocity of about 3000 to 3500 m/sec, always higher than its eventual steady-state value, and the transverse pressure oscillations that are generated at the same time reach an amplitude of almost 100 atm, while a steady plane detonation wave is able to raise the pressure to only 18 atm. The observed frequency of the oscillations is of the order of 70 kilocycles/sec. The exact nature of these waves and their origin are currently under investigation, particularly since they may shed light on one of the most important problems in rocket motor technology today.

the behavior of magnetically driven ELECTRIC ARCS

Ward C. Roman
Thermo–Mechanics
Research Laboratory
(ARL)

As a result of the interest in space exploration and technology, studies concerned with the behavior of plasma arcs driven by external magnetic fields have become quite important. The many possible uses of magnetically driven plasma arcs include high temperature aerodynamic research, space propulsion, and laboratory simulation of thermal re-entry conditions for material testing. Within the next few years, plasma arc technology is expected to receive increasingly widespread use in high-temperature re-entry simulation and space propulsion. Existing performance data and current trends indicate that major advances will be necessary to achieve the desired performance.

The extremely high current densities and heating rates encountered in arcs necessitate electrode cooling or moving the plasma arc rapidly over the electrode surfaces. Through the mechanism of magnetically driven plasma arcs, thermal loading of the electrode surfaces is greatly reduced thereby enabling much higher temperatures to be obtained in the arc, along with increased electrode life. Also, at extremely high power input levels, rapid movement of the cathode and anode spots is necessary to reduce contamination of the heated gas.

Although numerous investigators have built and operated d.c. electric arc devices at pressures greater than one atmosphere, no clear-cut understanding of the basic parameters which affect the motion and behavior of the arc under the influence of an external magnetic field has emerged. The complexity of the phenomena occurring in the ordinary plasma arc has caused a wide divergence of opinion as to which phenomena are fundamental to its operation. This is understandable in view of the complex collision phenomena between atomic particles, whose motion depends on their internal energy and superimposed electrostatic and electromagnetic force fields. Frequently, in order to predict the motion of an electric arc in a transverse magnetic field, many investigators have used a simple macroscopic model which compares the arc column with a current carrying cylindrical conductor. The arc motion is determined by the electromagnetic driving forces acting normal to the current and magnetic field vectors, counteracted

by an "aerodynamic drag" force. However, since the velocity of the arc affects the heat exchange from the column to its environment, this in turn affects the arc diameter, thus the drag. This model is greatly over simplified and does not sufficiently represent the actual complex phenomena involved. This area of investigation, therefore, is beneficial both to current Air Force space applications to purely scientific interest.

Ward C. Roman, conducting his masters's thesis study for the Ohio State University at the Aeronautical Research Laboratories, investigated some of the parameters which affect the fundamental process and characteristics of magnetically driven plasma arcs. The study presents information on the behavior and translational motion of plasma arcs (both a.c. and d.c.) driven by external magnetic fields (both a.c. and d.c.) along parallel rail, water-cooled copper electrodes at atmospheric pressure.

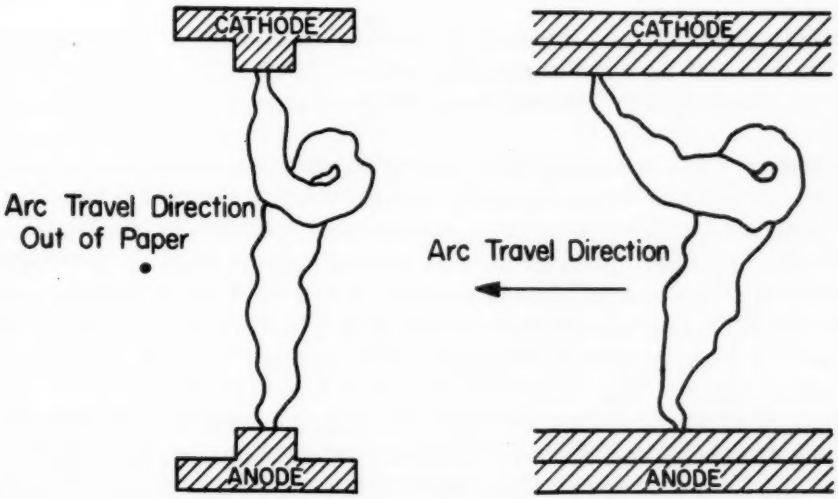
Dual-beam oscilloscope current and voltage trace photographs and high speed cameras, operated at speeds from 7,000 to 26,000 frames/sec, were the main means of investigation. The availability of these high speed cameras, with speeds 28 times that used by previous investigators, provided more accurate data and enabled 16m.m. color movies to be made of the arc behavior and translation motion. This improved details of frequently overlooked parameters since earlier photographic techniques did not allow sufficient time resolution for precise results.

Experimental data were obtained on the electrical characteristics of the arc, velocity of the arc up to 600 ft/sec, and the size shape, and color of the arc column as functions of various parameters. The variables were arc gap, electrode rail width, arc power input, (a.c. or d.c.), magnitude of externally impressed magnetic field, electrode arrangement, and finally, the addition of walls to the sides of the parallel electrodes to form a channel.

Because the mechanism of arc discharges is so complex and available information on the various physical processes and phenomena are in disagreement, it is extremely difficult to predict the effects of superposition of external magnetic fields on the arc discharge. It was illustrated by an over simplified picture of these combined effects that the arc column may not necessarily maintain its approximate cylindrical configuration as it is magnetically driven down the electrodes, but

may assume a helix or distorted shape.

The following two sketches illustrate how the arc column appeared from the two views for a given arc position.



The investigation indicated that the magnitude of magnetic field and arc current input play a dominant role in the driving force, which in turn directly affects the arc velocity. When compared with recent German and Russian publications, the experimentally determined equations and trends showed close agreement.

A unique feature of the present investigation, compared to other investigations in the field, was the two-dimensional viewing of the arc and the very simple but effective timing light apparatus to allow synchronization of the two high-speed cameras with the oscilloscope current and voltage traces.

The secondary effects of arc gap, electrode width, electrode arrangement and addition of channel walls on the arc behavior were plotted and compared with the work of other investigators. Close agreement was obtained in a majority of the data and where disagreement did exist, an attempt was made to explain by a simplified analysis some of the observed phenomena. An example of this was the

effect of channel walls on arc column behavior and terminal velocity. An earlier investigation of this in Germany indicated a trend of increasing arc velocity with walls added, whereas the present investigation showed a decreasing trend. A plausible justification of this phenomena was included in the discussion.

Also, of practical interest is the operation of a d.c. arc under the influence of an a.c. magnetic field, which has never been reported in the literature. Therefore a study of this was included.

Finally, this investigation provided data and information which determined areas requiring further studies. A few of these were: utilization of different electrode materials; electrode oxidation effect; refined heat transfer analyses; extreme close-up photography of arc spot motion (continuous versus discontinuous motion); and a forced blowing experiment to investigate a magnetically driven d. c. arc moving at high velocities against an airflow. This latter study will relate the driving forces to the aerodynamic drag forces over a wide range of velocities. Also of importance would be a theoretical analysis of other macroscopic models for the arc, e.g., chemical detonation, wave propagation, and chemical deflagration. These subjects will, where possible, be included in future research programs of the Thermo-Mechanics Research Laboratory.

AFCRL Notes

Two research rocket experiments were completed by AFCRL in September. During the week of September 10, an Aerobee rocket was fired from the White Sands Missile Range instrumented by AFCRL for measuring the intensity of day airglow. The vehicle, with a payload of about 190 pounds, reached a zenith of about 145 miles. The experiment was designed to measure the line emission spectra of the air above 80 Km during daylight, using a one meter Ebert scanning monochrometer with a photomultiplier detector. (Space Physics Laboratory)..... A second Aerobee was fired from the Eglin Gulf Test Range during the week of 24 September, instrumented to measure electrical properties of the lower ionosphere. The vehicle and its 200-pound payload reached a zenith of about 130 miles. At approximately 75 seconds, the nose tip and three side doors of the rocket were released to expose electron, ion density and electric field meter sensing elements. (Space Physics Laboratory)

International Photons

Lt Col William H. Wyatt, Directorate of Chemical Sciences (AFOSR)

On 18-22 June, 150 international scientists exchanged their ideas and concepts of photochemistry at the University of Brussels. This symposium was arranged by Professor Paul Goldfinger of the University and co-sponsored by the Air Force Office of Scientific Research through the European Office of the Office of Aerospace Research. Major subjects discussed were Energy Transfer, Processes in the Upper Atmosphere, Photolysis in the Gas Phase, Halogenations, Oxidations and Related Reactions, Reactions in Solutions, Reactions in Rigid Media, Polymerization Reactions of Biological Interest and Processes in Solid State and Photographic Processes.

Of direct interest to our aerospace programs were papers on photochemical processes in the ionsophere, mechanisms of the night airglow, chemiluminescent reactions in the upper atmosphere and chemical reactions of excited molecules. Professor Paul Harteck of RPI, an AFOSR investigator, gave an exciting discussion of the chemiluminescence of the upper atmosphere. He is interested in illuminating the night sky by appropriate chemical reactions with the reservoir of oxygen atoms at these high altitudes. Reactions of nitrogen and oxygen in the chemosphere were discussed by Professor M. Nicolet of Brussels. Oxygen and nitrogen are atomic rather than molecular at these altitudes. These reactions may be very important to an understanding of the aurora and night airglow.

Other AFOSR investigators were Drs. Robert Reeves of RPI, Kyle Boyes of UCLA and W. A. Noyes, Jr. of Rochester University. Their research and papers have contributed very valuable information to a better understanding of the photochemistry processes. Of biological interest was a paper by Bertel Holmström on photolysis of riboflavin as the photolysis process plays a very important role in the life cycle of plants.

From these international discussions, ideas were generated which will keep the attendees busy for many months. Fundamental knowledge of photochemistry will aid in developing better materials and designing communications equipment for our space flights.

and still more fundamental particles ?

Ray R. Heer, Jr., Nuclear Physics Division (AFOSR)

The time is the early 1930's. The situation in physics is rather unexciting; significant figures are slowly increasing to the right of the decimal point. The family of fundamental particles numbers only three; the proton, the electron and the recently discovered neutron. Quantum mechanics is doing a good job describing the atomic behavior of matter. The chemists and biologists, as well as the physicists, are beginning to make use of quantum theory in terms of which, in principle, atomic physics can be completely understood. Then - someone rocked the boat. Someone wanted to know more about the nucleus -- about the nature of the matter.

Now skip about thirty years -

What do we know about the nucleus? Well, we know the nuclear domain is about 10^{-5} the linear size of the atomic domain. And we know that quantum mechanics gives only order-of-magnitude answers when applied to certain sub-nuclear problems. The basic principles are not well understood. We don't even know, explicitly, the basic law which describes the force operating between a proton and a neutron - two real old timers. And the crystal ball may be getting cloudier, since we now know thirty odd particles and antiparticles and an unagreed-upon number of resonances (resonances sometime can be described by the same parameters as can particles) and more are predicted to exist. Some of these particles were predicted by theory before being identified - H. Yukawa's prediction of the pi meson is probably the most famous. All of the particles have been found to be produced in high energy interactions which occur either in nature or in accelerators. We do not understand the relationship of all these particles to each other. In fact, we don't know if all the particles which are called "fundamental" should be so called or if some are combinations of other particles already catalogued. Or, if they are, if this is proper grounds for disqualification. In general, the term 'fundamental' is applied to particles which 'live' a very long time compared to typical nuclear reaction times. Though - of course - even this definition isn't hard and fast.

Concerning lifetimes - we have learned something; they appear

to be basically related to mass and charge. A mass excess appears to make a particle less stable (shorter lifetime) and a finite charge appears to make it more stable (longer lifetime). For example, it is well known that a neutron decays to a proton plus an electron with a half life of about 11 minutes and that the mass of the neutron is more than the combined mass of the proton and the electron. It is quite possible that if the neutron were heavier than the proton by less than the mass of the electron, the neutron would be stable, or at least more stable than it is. In any case, its present mode of spontaneous decay would be denied it. In the case of charge, the uncharged pi meson or sigma hyperon decays more than a million times faster than its charged counterpart. In each case a well established conservation law is working; in the first, that of mass plus energy and in the second, that of charge.

In the last twelve months there have been four new resonances, or particles, discovered. They are called the rho, omega, eta and zeta. Professor Aihud Pevsner and his group at Johns Hopkins University which has been supported by the Air Force Office of Scientific Research for a number of years have contributed mightily to these new findings. They discovered the eta - a three π resonance of mass 546 Mev and lifetime of about 10^{-22} seconds, confirmed the omega by checks of spin-parity and isotopic spin, and have contributed to the description of the rho and zeta. Each of these four mesons fits, to a greater or lesser degree, a prediction of one or another of the theories of fundamental particles. In particular, Gell-Mann and Sakurai in this country and Heisenberg in Germany have predicted them.

It seems probable to the writer that the reader may be formulating a question which goes something like 'But why is the Air Force interested in these particles - in this sort of thing?' An explicit answer is not possible. But when one considers how impractical and inapplicable Einstein's Special Theory of Relativity and the statement of equivalence of energy and mass ($E=mc^2$) were in 1906, or Rutherford's 1911 confirmation that the mass of the atom was concentrated in the nucleus, or Chadwick's identification of the neutron in 1932 - and how indispensable all of these facts are to what we call atomic energy - controlled or otherwise - it is not possible to escape the conviction that the Air Force must be vitally concerned with the rapidly developing field of fundamental particle physics.

research in

EXTRASENSORY PERCEPTION

Communications Sciences Laboratory (AFCRL)

A large scale scientifically rigorous, experiment in the field of extrasensory perception was recently completed by AFCRL. Preliminary investigations and experimentation covered a period of about one year. During the experimental phase 80,000 responses by 45 test subjects were recorded and analyzed.

Extrasensory perception has long been a matter of controversy among scientists. To give credence to apparent manifestations of the phenomena in its many forms the scientist must entertain the idea of some unknown force, which he is often unwilling to do.

AFCRL's primary goal was to develop an experimental design, and an objective test of extrasensory perception phenomena (precognition, clairvoyance, and telepathy) rather than to evaluate the validity of the concept as such. This goal arose out of the desire to establish within the Air Force, and therefore within the Department of Defense, an authoritive knowledge and a base of experience in the field of parapsychology.

Parapsychological investigations of ESP are being made in several U.S. and European universities. In the Soviet Union several large scale efforts of this nature are actively supported by the government.

The AFCRL experiment was designed and conducted by Electronics Engineer Everett F. Dagle, Physicist John Mott-Smith, Mathematician Margaret D. Hill, of AFCRL, and Psychologist Dr. William Reed Smith, formerly of AFCRL and now with Northeastern University.

The key element of the experiment consisted of a special purpose machine, called the VERITAC, which had been designed by Mr. Dagle.

The VERITAC has the capability of generating random numbers from 0 through 9, and automatically recording the responses and reaction time intervals of the subjects. By conducting all tests with this machine, any subtle bias or mannerisms by test administrators or test scorers that might give clues to the subject, or result in scoring errors, were eliminated. The VERITAC permitted tests to be made in two modes: 1) the subject could attempt to predict the number which would be generated, and 2) the subject could attempt to, clairvoyantly or telepathically, determine which number had already been generated and displayed as a bright "target" in another room.

Through the interest and cooperation of President George O. Bierkoe and the administration of Endicott Junior College at Beverly, Massachusetts, physical facilities and test subjects were provided at no cost to the Air Force. Out of a group of sixty volunteers, forty-five actively participated in the experiment with thirty-seven of the group completing the entire series of tests. In an attempt to determine whether extrasensory capability might be related to unique personality traits, all subjects were given a well validated personality test.

Preliminary analysis of the test results show no significant deviation from statistical norms, and the group, taken as a whole, showed no unusual ability to either predict events or to determine, clairvoyantly or telepathically, that a particular event had taken place.

It is felt that the data obtained during this experiment will uncover some interesting information on decision making as a function of personality make-up. The attempt to guess or predict numbers, under the conditions of this experiment, is essentially a decision-making process. It is hypothesized that depending on personality, time between responses, and the pattern of responses will be found to vary considerably.

The first complete report of the experiment will be issued in the very near future. Later reports which are expected to be issued will cover: The Nature of Responses by Personality Groupings; Hits and Misses as a Function of Reaction Time; The Kinds of Hits and their Distribution; Random and Non-Random Selections; Equipment Design.

CHEMICAL RELEASES in the UPPER ATMOSPHERE

SPACE PHYSICS LABORATORY (AFCRL)

About 30 research rockets will carry various chemical payloads to altitudes of from 50 to 150 miles under a two-month long AFCRL Program which began about 15 October. The upper atmosphere chemical releases program is conducted under AFCRL's Project Firefly.

Part of the payloads are intended to create a higher than normal electron density in the ionosphere for over-the horizon communication studies. Other payloads are designed to remove electrons from the F-layer to generate a "hole" in the ionosphere. There will also be releases of chemicals which interact with ambient species producing a glow. This glow can be observed at night enabling the tracking of the released material to measure upper atmosphere winds. Finally, there will be mixtures exploding at high altitudes to observe shock wave perturbations of the ionosphere. Both solid and liquid propelled high altitude research vehicles will be used as carriers for these experiments. These vehicles will include approximately 16 Nike Cajuns, 9 Honest John Nike Nikes, and 5 Aerobee 150's.

The experiments are planned and conducted by AFCRL under the direction of Dr. Norman Rosenberg. The rockets used in the experiments will be launched from Eglin AFB, Florida.

AFCRL has conducted research concerned with chemical releases at high altitude for a number of years. Depending on the particular effect under study --- electron decay process, mass transport, chemiluminescence and so on --- various chemicals are used. Among the chemicals of interest are cesium nitrate-aluminum mixtures and alkali seeded tetracyano-ethylene and hexanitroethane , and cesium.

The resulting electron clouds are observed by reflected and scattered radar echoes. The radar cross-sections differ depending on altitude of release, time of day, and wind shear. Based on past experiments, the electron cloud is sufficiently concentrated to serve as a reflector of a 50 Mcps signal for about 30 minutes or so during the day, and for about 10 minutes at night.

NOTICE TO OUR READERS

Requests for further information should be directed to the individual or laboratory of origin.

Addresses are as follows:

For articles originating within Air Force Cambridge Research Laboratories:

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
Attn: CRI
Laurence G. Hanscom Field
Bedford, Massachusetts

For articles originating within Aeronautical Research Laboratories:

AERONAUTICAL RESEARCH LABORATORIES
Attn: ARO
Wright-Patterson Air Force Base, Ohio

For articles originating within Air Force Office of Scientific Research:

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Attn: SRIL
Tempo D Building
4th and Independence Avenue, S.W.
Washington 25, D.C.

For documentary reports on research referred to in articles:

*ARMED SERVICES TECHNICAL INFORMATION AGENCY
Arlington Hall Station
Arlington 12, Virginia

OFFICE OF TECHNICAL SERVICES
U.S. Department of Commerce
Washington 25, D.C.

* Qualified requestors.

RESEARCH REVIEW is published by the Office of Information (RREI), Office of Aerospace Research, USAF, Washington 25, D. C. The frequency of this publication is determined solely on the basis of the availability of significant material to report. The objective is to make a positive contribution to the exchange of information about Air Force sponsored and conducted basic research activities. Individuals or groups associated with basic research may obtain copies by written request to the above address.

GPO 935345